(12) UK Patent Application (19) GB (11) 2 296 152 (13) A

(43) Date of A Publication 19.06.1996

(21) Application No 9501859.4

(22) Date of Filing 31.01.1995

(30) Priority Data
(31) 9425119 (32) 13.12.1994 (33) GB

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(51) INT CL^6
H04N 13/04

(52) UK CL (Edition O)
H4F FDD FD15 FD27B FD27C9 FD27F FD27T1 FD40P FD42C9 FD42V
U1S S2285

(56) Documents Cited
GB 2272597 A GB 2272555 A GB 2206763 A
EP 0570179 A2 EP 0541374 A1

(58) Field of Search
UK CL (Edition N) H4F FDD
INT CL^6 H04N 13/00 13/04 15/00
Online: WPI

(54) An autostereoscopic display

(57) An autostereoscopic display comprises a first light source 4 and a second light source 5, the radiation from which is focused by an optical arrangement 6, 8 on respective eyes of an observer in viewing zones 9 and 10. A spatial light modulator 7 modifies the radiation received by each eye such that each eye receives a respective first and second image of a stereoscopic image pair. The light sources may be of different wavelengths with the spatial light modulator comprising two sets of wavelength selective elements each set producing respective first and second images, or the light sources may be controlled in combination with the modulator 7 to produce respective frame sequential image pairs.

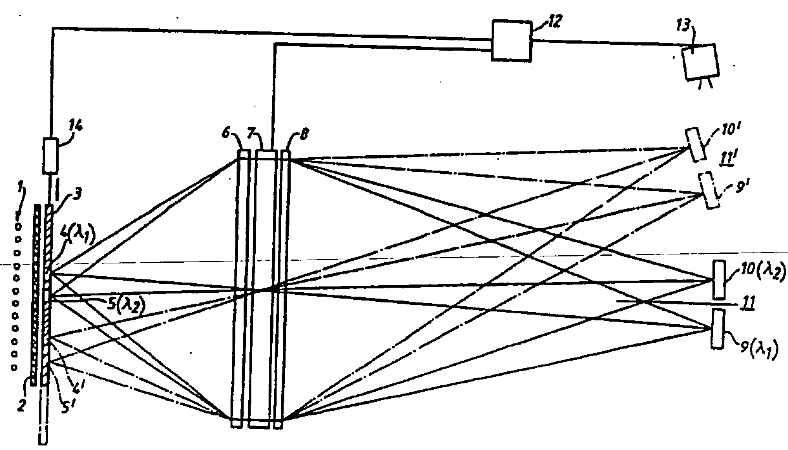

Fig.1

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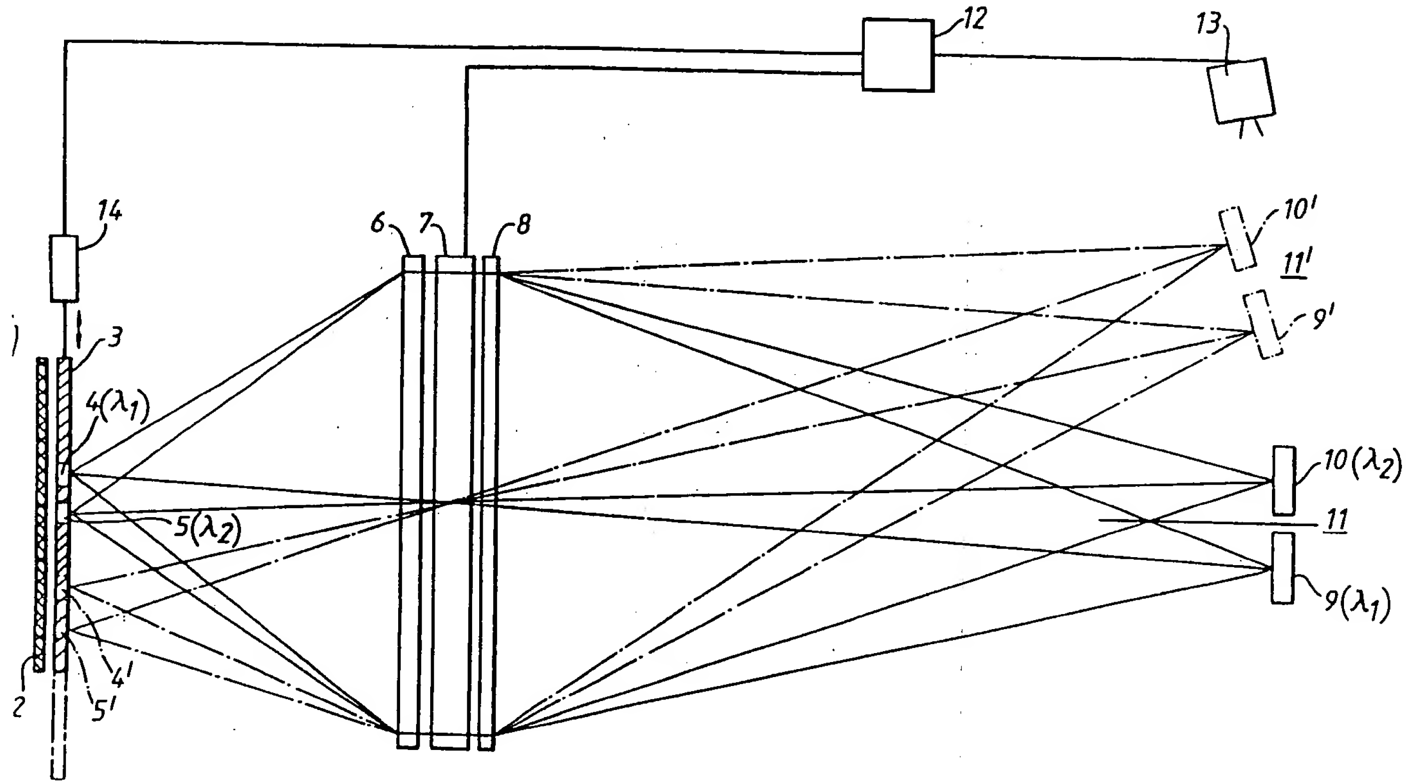
1
2
3
4(λ_1)
5(λ_2)
4'
5'
6
7
8
9(λ_1)
10(λ_2)
11
9'
10'
11'
12
13
14

Fig.1

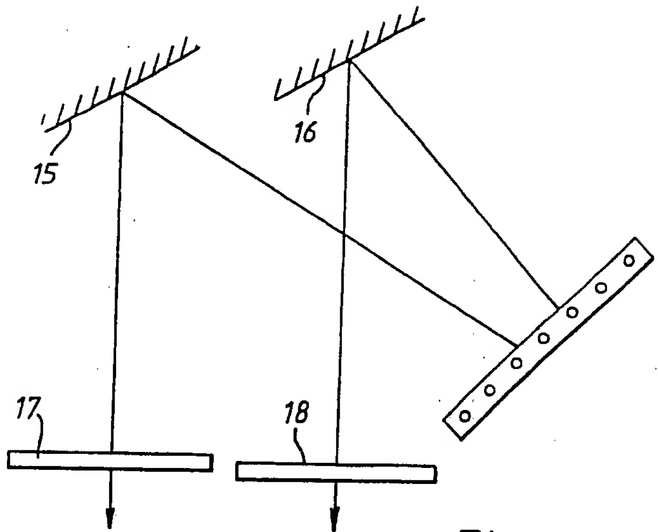

Fig. 2a

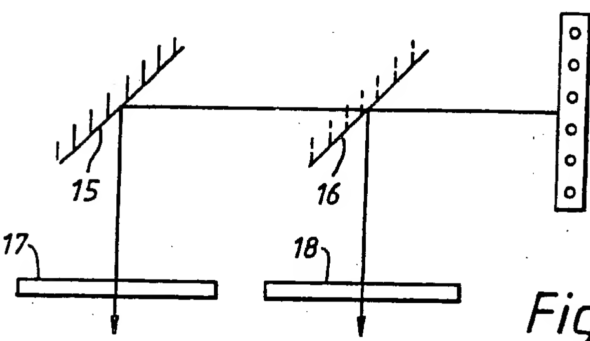

Fig. 2b

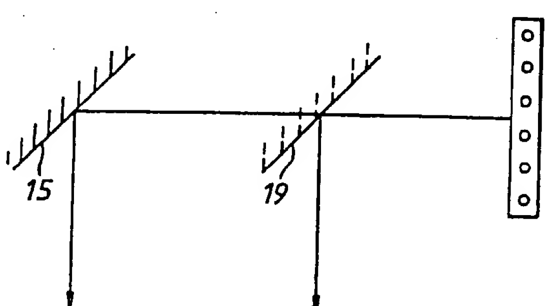

Fig. 2c

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AN AUTOSTEREOSCOPIC DISPLAY

The present invention relates to an autostereoscopic display, that is, a display which provides a stereo image which can be viewed, in stereo, without an observer having to wear special eyewear.

Many applications for display products benefit greatly from the extra information and impact generated by stereoscopic (3-D) images. The entertainment industry has made use of various 3-D techniques for many years and more recently medical imaging, molecular design and engineering design disciplines have experimented with 3-D techniques.

Most of the displays used in the above industries have been based on the well-known techniques of providing left/right eye views by providing the observer with glasses which select the appropriate view based on colour selectivity, orthogonal polarisations or synchronised shuttering techniques.

More recent developments have produced a number of autostereoscopic display techniques based on a variety of holographic, optical and electro-optical techniques. These displays are typically expensive, requiring either multiple viewing cameras and display elements, or contain difficult to manufacture holographic components often with moving parts, or are difficult to assemble requiring accurate sub-pixel alignment of lenticular arrays behind LCD devices. Examples of such displays are given in articles in SPIE Vol. 2219 Cockpit Displays (1994) by: G.R. Little et al, "Multiperspective

autostereoscopic display", pages 388-394; and J. Eichenlaub et al, "An in-cockpit 'situation awareness' autostereoscopic display", pages 395-406.

The present invention aims to provide a low-cost display device which uses readily available components, has no critical alignment requirements, and can provide 2-D or 3-D images.

According to the present invention there is provided an autostereoscopic display comprising: means for supplying light from first and second positions; an optical arrangement for directing light from each of the said positions to respective eyes of an observer in a viewing zone; a spatial light modulator for modifying the light transmitted to the observer from the first and second positions; and means for controlling the spatial light modulator such as to generate first and second images as viewed by respective eyes of the observer.

In a conventional cathode ray tube (CRT) display and most other emissive displays, the light generating function and the spatial brightness modulation of the emitted light take place on the same surface, e.g. the phosphorous screen of the CRT. With such displays it is only possible to produce stereoscopic pairs of images of different wavelengths by providing an observer with an appropriate pair of filters, one for each eye, normally in the form of a pair of glasses. The present invention arises from a realisation that with spatial light modulators, such as a liquid crystal display (LCD), the light generating function is separate from the spatial modulation, with a backlight for the LCD normally being placed directly behind the screen. By providing light from two positions, or two

light sources, relative to the spatial light modulator and directing light from the two positions, or light sources, to respective eyes of an observer then light from the two positions in combination with appropriate control of the spatial light modulator can be used to provide an autostereoscopic display to an observer.

According to one embodiment of the invention, the means for supplying light is such as to supply light of first and second wavelengths respectively from the first and second positions; the spatial light modulator comprises a first set of elements for modulating light of the first wavelength, and a second set of elements for modulating light of the second wavelength; and wherein the control means activates the first and second sets of elements to respectively modify the light transmitted to the observer from each of the said positions such that first and second images are observed by respective eyes.

By having a light incident on the display from two positions of respective different wavelengths, separate from the spatial light modulator, appropriate image pairs can be presented to respective left and right eyes of an observer by controlling wavelength selective elements of the spatial light modulator, which elements, in conjunction with the separated positions, provide the filtering effect previously implemented by coloured spectacles. One limitation of using light of different wavelengths is that, (without going into complex arrangements of light sources requiring each light source to be switchable between a number of different wavelengths, and controlling the spatial light modulator in a correspondingly complex manner) only a monochrome image, comprising two primary components, is apparent to the observer. If it is desirable to produce a display other than a monochrome image, then this can be achieved according to a second

embodiment of the invention.

According to a second embodiment of the invention the means for supplying light is designed to be switched so as to supply light alternately from the two positions, the control means being synchronised to the said switching so as to generate the first and second images when light is supplied from the first and second positions respectively. In this way a full colour display can be generated by generating on the spatial light modulator a first and a second set of frame sequential images associated with the first and second positions, and therefore left and right eyes respectively. If a conventional LCD display is employed then, because of the relative switching speeds of such displays, some flicker or image smearing may be apparent. Preferably an LCD having a high switching speed is employed, such as a ferro-electric LCD, to overcome this problem.

It is preferable that the spatial light modulator comprises a liquid crystal display because such displays are readily available at relatively low cost, however the invention is equally applicable to any addressable screen with a variable electro-optic function, including reflective type displays located in the optical path.

Preferably the spatial light modulator is planar and the optical arrangement comprises a Fresnel lens adjacent to the modulator. Such a lens provides a convenient way of focusing the light across the whole of the modulator and can have a focal length suitable to provide an image of the backlight in the required viewing zone. If the spatial light modulator is transmissive the lens may be either in front or behind the spatial light modulator. However, it is particularly advantageous that the lens arrangement causes

light from both light positions to be incident at an angle substantially perpendicular to the plane of the modulator over the surface of the modulator. Because most spatial light modulators such as LCDs have transmission characteristics which are dependent upon the angle of incidence of the illuminating light, this ensures that the transmission characteristics are substantially uniform across the whole surface of the spatial light modulator. This is particularly important in a stereoscopic application for if the display exhibits a varying response to the light received from the two positions then the quality of the stereo effect is degraded.

It is particularly advantageous if a Fresnel lens is located adjacent either side of a transmissive spatial light modulator. This enables the total available optical power of the imaging system to be increased, enabling the backlight to LCD spacing to be reduced providing a more compact display. Also it permits the light rays which pass through the spatial light modulator from the whole of each position to transverse the spatial light modulator at similar angles, especially if the lens between the light positions and the spatial light modulator has a focal length close to the desired backlight to spatial modulator spacing with the lens between the spatial light modulator and the observer having a focal length equal to the desired distance between the modulator and the observer.

If it is desired that the display be viewed by a number of observers, then if the display backlight comprises a plurality of first and second light positions a number of stereoscopic image pairs can be generated to a plurality of viewing zones so that a number of observers can view a stereoscopic image simultaneously.

It may be advantageous that the display includes means for monitoring the head position of an observer and means for moving the first and second positions such that the viewing zone follows the movement of the observer's head. The physical position of the light sources need not be altered, instead this can be achieved by displacement of the lens arrangement. If the images are computer generated, then preferably the computer also modifies the images in response to the movement of the head such as to present a pseudo-parallax effect to the observer, maintaining the observer's perspective and thereby enforcing the 3-D effect. Similarly if the images are being produced by a camera pair then moving the cameras to follow the head will give a true parallax stereoscopic view.

The present invention will now be described by way of example only, with reference to the accompanying figures, of which:-

Figure 1 is a schematic diagram of a display in accordance with the present invention; and

Figure 2 illustrates alternative arrangements of light sources.

Referring to Figure 1, the display comprises an array of fluorescent tubes 1, a diffuser 2 and a non-transmissive screen 3 having apertures 4 and 5 each having wavelength selective filter elements located therein. The filter element in aperture 4 is transmissive to red light of wavelength λ_1 and the filter element in aperture 5 to green light of wavelength λ_2. The two filter elements in combination with the diffuser and fluorescent

tubes act as light sources, light from which is incident on the surface of Fresnel lens 6 and LCD 7. The Fresnel lens 6 in combination with a further Fresnel lens 8 focuses the radiation at viewing zones 9 and 10 respectively.

An observer with his head at position 11 looking at the LCD 7 observes radiation focused in his left eye, in viewing zone 9, from aperture 4, and radiation focused in his right eye, at viewing zone 10, from aperture 5. With all the elements of the LCD being in a transmissive state, the LCD appears to the observer to be uniformly lit, light being directed by Fresnel lens 6 through all the elements of the display 7 in a direction substantially mutually perpendicular to the plane of the display, such that the transmission characteristics are uniform across the display.

The LCD is in this specific example a 21.5 cm diagonal three colour LCD display, two of the colours, red and green, corresponding to the wavelengths of the filters in apertures 4 and 5 respectively. Ideally the LCD 7 would be a two colour display, but three colour displays are readily available, as is the hardware and software for driving such displays. The redundant blue pixels, or elements, do not degrade the performance of the display to any significant extent.

The red and green pixels of the LCD 7 are driven by control circuitry 12 to produce a red first image and a green second image of a stereoscopic pair of images. Because red light (λ_1) from filter in aperture 4 is only received by the left eye, the observer at 11 only sees the "red image" with his left eye, the first image of the stereo pair of images. Likewise he only receives the "green image", or second image of the stereo pair, with his right eye.

These images are combined by the brain to give a 3-D monochrome image which is yellow.

Each of the filter elements in apertures 4 and 5 is 3 cm wide and 4 cm high. These filters are located 15 cm behind the LCD. The observer is located some 30 or 40 cm in front of the LCD display. An observer can raise or lower their head quite substantially without any noticeable effect on the viewed image, the image simply fading out when the person's eyes are no longer in the viewing zones 9 and 10. The distance between the observer and the display is also not critical, the observer requiring to move in excess of 10 cm forward or backward before they start to receive both red and green light sources in any one eye to an extent where the stereoscopic effect is noticeably degraded. However, lateral movement of the head by more than 3 cm brings one eye into the "wrong" zone.

In applications where lateral movement of the head is desirable, for example in head-up display applications, head or eye position detecting means 13 is provided to track the position of the observer's head. The signal from the position detecting means is fed to controller 12 which in turn controls actuator 14 which slides the screen 3 containing filter elements in apertures 4 and 5 in an opposite direction to that in which the observer moves. If the observer moves to position 11' then screen 3 is moved such that apertures 4 and 5 are at positions 4' and 5' causing the viewing zones 9 and 10 to track the position of the observer's head to position 11'.

If a display is to be viewed simultaneously by two observers, then two sets of filter

elements are located in two sets of apertures at 4, 5 and 4', 5'. Two observers located at positions 11, 11' can then simultaneously view the display. Similarly, three or more pairs of apertures can be included to provide a corresponding number of viewing positions.

It will be appreciated that many alternative light sources can be used, for example instead of fluorescent tubes and filter elements an array of coloured LEDs could be employed. Furthermore, using such an array of LEDs would enable the optimum viewing zone to be moved simply by "walking" regions of illuminated pixels corresponding to the two different colour light sources across the array of pixels such that viewing zones 9 and 10 track the position of the observer. Similarly if the switching speed of the LCD is sufficiently fast, the regions of each light source could be switched between the three primary colours, with each image on the LCD being switched in synchronism between the same three sets of primary colours of the LED pixels such as to display three corresponding images synchronised to the switching of the LCD, thereby generating in each eye a full colour display due to the persistence of vision.

A simpler approach to a full colour display is obtained by placing shutters in apertures 4 and 5 which shutters open and close in antiphase in synchronism with the LCD. The LCD then displays a first image of an image pair when a first shutter is opened, and a second image of an image pair when the second shutter is opened. Each eye of an observer sequentially receives full colour first and second images in respective left and right eyes. In such an arrangement a suitable display is a ferro-electric LCD display for this has a fast enough switching time to ensure that the eye does not perceive the flicker associated with each shutter being shut for 50% of its cycle. Head tracking and multiple

viewing is achieved in exactly the same way as described above.

Whether a full colour display or monochrome display is generated, if the image displayed is computer generated and the position of the observer's head is tracked, then the computer 12 modifies the image on the LCD in dependence on the position of the observer's head in order to present a pseudo-parallax effect providing an enhanced 3-D effect to the observer as he changes position.

Where it is desirable to display images received from two cameras of a camera pair (not shown) the camera pair is controlled in dependence on detected movement of the observer's head, thus permitting the observer to "look around".

If in any of the above arrangements it is desirable to present a 2-D image to the observer, then this is achieved by displaying the same image, colour or monochrome, to both eyes of the observer. The display can therefore be used to present both 2-D and 3-D images without any modification.

In the displays described above the observer views the spatial light modulator directly. However the display could be viewed indirectly by means of a reflection from a car windscreen, or could be incorporated in a head-up display.

In alternative embodiments of the present invention, the two light sources 4, 5 may be provided by an arrangement of mirrors 15, 16 as illustrated in Figures 2a or 2b, which mirrors receive light from a common source of light and then define separate light

sources in combination with filter elements 17, 18, or, as illustrated in Figure 2c, one mirror 19 may be frequency selective such that mirrors 15 and 19 themselves define the separate light sources.

CLAIMS

1. An autostereoscopic display comprising: means for supplying light from first and second positions; an optical arrangement for directing light from each of the said positions to respective eyes of an observer in a viewing zone; a spatial light modulator for modifying the light transmitted to the observer from the first and second positions; and means for controlling the spatial light modulator such as to generate first and second images as viewed by respective eyes of the observer.

2. A display as claimed in claim 1 wherein: the means for supplying light is such as to supply light of first and second wavelengths respectively from the first and second positions; the spatial light modulator comprises a first set of elements for modulating light of the first wavelength, and a second set of elements for modulating light of the second wavelength; and wherein the control means activates the first and second sets of elements to respectively modify the light transmitted to the observer from each of the said positions such that first and second images are observed by respective eyes.

3. A display as claimed in claim 1 wherein the means for supplying light is designed to be switched so as to supply light alternately from the two positions, and wherein the control means is synchronised to the said switching so as to generate the first and second images when light is supplied from the first and second positions respectively.

4. A display as claimed in any preceding claim wherein a plurality of first and second images are formed such that an observer views a moving three dimensional

image.

5. A display as claimed in any preceding claim wherein the spatial light modulator comprises a liquid crystal display.

6. A display as claimed in any preceding claim wherein the spatial light modulator is planar and the optical arrangement comprises a Fresnel lens adjacent to the modulator.

7. A display as claimed in any preceding claim wherein the spatial light modulator is planar, modulates light transmitted therethrough, and wherein the optical arrangement causes the light from both positions to be incident at an angle substantially perpendicular to the plane of the modulator over the surface of the modulator.

8. A display as claimed in claim 7 wherein a Fresnel lens is located adjacent either side of the spatial light modulator.

9. A display as claimed in any preceding claim in which the means for supplying light comprises a plurality of pairs of first and second positions from which light is supplied and in which the optical arrangement is such as to provide a corresponding plurality of stereoscopic image pairs to respective viewing zones.

10. A display as claimed in any preceding claim including means for monitoring the head position of an observer and means for moving the first and second positions such that the viewing zone follows the movement of the head.

11. A display as claimed in claim 10 wherein the displayed images are computer generated and wherein the computer modifies the images in response to detection of movement of an observer's head such as to present a pseudo-parallax effect to the observer.

12. A display as claimed in any one of claims 1 to 10 wherein the first and second images are generated by first and second cameras of a camera pair.

13. A display as claimed in claim 10 further comprising a camera pair for generating the first and second images and means for controlling the camera pair in response to movement of an observer's head.

14. A display as claimed in any one of claims 1 to 9 wherein a 2-D image is observed by an observer when the first and second images are the same.

15. An autostereoscopic display substantially as hereinbefore described with reference to, and as illustrated in, Figure 1 of the accompanying drawings.

16. An autostereoscopic display substantially as hereinbefore described with reference to, and as illustrated in, Figure 1 modified as shown in Figure 2a, 2b or 2c of the accompanying drawings.

Patents Act 1977
E miner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9501859.4

Relevant Technical Fields

(i) UK Cl (Ed.N) H4F (FDD)

(ii) Int Cl (Ed.6) H04N (13/00, 13/04, 15/00)

Search Examiner
MR J M McCANN

Date of completion of Search
13 MARCH 1995

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) WPI

Documents considered relevant following a search in respect of Claims :-
1

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2272597	(SHARP) see abstract and Figure 5	1
X	GB 2272555	(SHARP) see Abstract and Figure 3	1
X	GB 2206763	(A.R.L. TRAVIS) see Figure and Abstract 2	1
X	EP 0570179 A2	(SHARP) see Abstract and Figure 2	1
X	EP 0541374 A1	(SHARP) see Abstract and Figure 1 and 2	1

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